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NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

FERRO CEMENT PANELS
VOLUME II

Military Uses and Installation

November 1968

An Investigation Conducted by
T. Y. LIN AND ASSOCIATES
Consulting Engineers
Van Nuys, California

N62399-68-C-0040

Introduction

The evaluation of ferro cement panels by means of a series of experiments and conclusions reached regarding the protection to be expected from them are presented in Volume I of this report. The conclusions pertain to their use in revetments, bunkers, "concrete sky" aircraft cover and protective fenders around bridge piers.

Volume I also describes two methods used in casting panels and the problems encountered, reviews the two methods comparatively and presents the lessons learned from the experience.

This volume presents recommended methods for the use and installation of ferro cement panels in revetments, bunkers, "concrete sky" and pier fenders.

There will be situations and conditions in combat operations in which modifications will be advantageous. The recommended uses and installation will provide a point of departure and guidance for modifications in such cases.

FINAL REPORT — VOLUME II

Contract N62399-68-C-0040
Report No. CR 69.008

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FOREWORD

The results of this investigation are contained in two volumes. Volume I contains evaluations of an experimental series to determine the protective potential of ferro cement. Volume II provides recommendations for military protective uses and installation of ferro cement panels in the building of revetments, bunkers, "concrete sky" aircraft cover, and fenders around bridge piers.

Abstract

Prefabricated revetment sections, 3 feet wide and of the required height in a mutiple of 3 feet, consisting of two layers of 3'x3'x1" panels secured at their vertical edges to wood 2x8's, are recommended for revetments. They are to be tilted up and secured at their tops to a timber rail between posts set in the ground at 9' spacing. Vertical timbers mounted and braced on horizontal timbers may be used instead of posts on paved areas.

For bunkers in prepared defensive positions, revetment sections are recommended for the walls and roof. In hasty defense resulting from a meeting engagement, single 1" panels about 4 square feet in area will reinforce hastily dug-in protection. Their availability in a meeting engagement, however, may be problematical.

For "concrete sky", blanketing layers of 3'x3'x1" panels, fabricated in place over an arched supporting structure are recommended, with multiple layers separated 6" or more by timber spacers secured to the layers beneath them.

For pier fenders, it is recommended that prefabricated sections, consisting of two 4'x4'x2" panels secured to wood 4x6's at their edges and filled with urethane or polystyrene foam, be suspended from the bridge superstructure by means of steel wire strands.

VOLUME II

Military Uses and Installation of Ferro Cement Panels

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Section 1

General

1.1 Panel Dimensions and Reinforcement

Panels 1" in thickness, used in a two-panel tandem arrangement, are recommended for revetments, bunkers and "concrete sky" aircraft cover. The panels are reinforced from form bottom to screed line with closely spaced, soft steel mesh, such as expanded metal lath or ¼" hardware cloth. The dimensions are influenced by weight for man-handling, dimensions in which reinforcement may be readily procured, truck bed loading and the intricacy of the structure required to support them. The density of the panels will average about 150 pounds per cubic foot which is 12.5 pounds per square foot for 1" panels.

Panels of 2" thickness are recommended for pier fenders, which should consist of two arrays of panels, one within the other, at least 3 ft. apart, completely surrounding each pier. Since lifting equipment such as a fork lift will be required for loading trucks at the casting yard and hoisting equipment will be required at the bridge, both for any reasonable size of 2" panel, the size will most likely be governed by truck bed loading. It may be necessary to abut two strips of reinforcement to make each layer unless large quantity procurement will encourage manufacture of the material in the required width. This will introduce lines of weakness which may be distributed four ways by rotating the layers. These panels will weigh about 25.0 pounds per square foot, so a 4'x4" panel will weigh about 400 pounds.

1.2 The Attachment of Panels

During underwater blast experiments, 3'-5½"x3'-5½"x2" panels were suspended from a pair of pipe rails by passing 1/4" diameter steel wire cables through holes drilled at the corners with about 4" edge distance and looping the cables over the rails. When exposed to blast, some of the panels snapped the cables and none of them revealed cracked cement or other signs of distress at the holes. A ½" diameter hole was drilled in a 2" panel with a carbide tipped bit in an electric drill in 1-3/4 minutes. The

first inch was drilled rapidly. As the hole became deeper, the granulated cement did not discharge as readily. With deviation from holding a fixed line which was unavoidable with a hand held drill, the bit seized and slipped the chuck several times, necessitating withdrawal of the bit to clean out the granulated cement. With a high speed drill-press rigged with a turntable bed to facilitate rotating the panel, holes in the four corners may be drilled in five minutes. A small air jet alongside the bit would hasten the discharge of granulated cement.

Open holes at the corners, enabling connectors to be attached at the construction site, will leave the panels free of protrusions for flat stacking in storage and for hauling in trucks.

Another type of connection which will do away with hole drilling consists of pieces of 20 g, mild carbon steel sheet fastened to the panel by means of power driven nails. These nails are designed to be driven into concrete and are used mainly for attaching nailer strips. They are driven by a rim fire cartridge, similar to a Cal. .22 blank cartridge, which is fired in a handgun designed for the purpose. The gun is loaded with a nail and a cartridge, pressed hard against the surface into which the nail is to be driven and fired. They are manufactured by the Winchester Western Division under the trade name, "Ramset," and there may be others. These connections would be made in their entirety at the site where the panels were being used. Cement nails or masonry nails may easily be hand driven with a heavy hammer.

Section 2

Revetments

2.1 General

Since revetments of precast panels are essentially walls, there are many ways in which they may be built. The simplest form of construction would consist of posts, 8" in diameter or 8"x8" (nominal) and rails, 4"x8" (nominal) which would space the 1" panels at about 7½", with panels 36"x36"x1", weighing about 113 lbs. The panels may be attached with lag screws through drilled holes. The weight of the upper tiers of panels would bear on lower tiers and the lower tier would bear on sills on the ground, thus minimizing sag in the rails.

2.2 Tilt-up Revetment Construction

The tilt-up method of construction using prefabricated revetment sections is recommended. An isometric view of a 3' revetment section is shown in Figure 1. The section may be prefabricated to the required height in a multiple of 3 feet (3', 6', 9' or 12').

After the sections are fabricated as shown in Figure 1, they are to be capped by a 2x10, 3 ft. long nailed to the ends of the 2x8's.

The supporting structure is to consist of posts at 9 ft. spacing with a rail positioned so its top surface will be flush with the 2x10 cap of the section when the section is tilted up. For adequate wind resistance posts should be 8"x8" rough-sawn or 10"x10" nominal for a 12 ft. revetment. A nominal 8x8 is adequate for a 9 ft. revetment. The posts should be set 3 ft. into the ground. A rail, 6"x6" rough-sawn or 8"x6" nominal will be required. An 8"x6" must be installed with the 8" sides horizontal. The sections are to be tilted up against the rail and secured to it by means of two 20g. sheet steel fasteners per panel, nailed to the rail and the 2x10 cap of the section. A plan of the connection is shown in Figure 1.

On pavement or stabilized soil, standards consisting of posts set on sills and braced to them may be used instead of posts set in the ground. Sills should be of the size and length of the post and be weighted at each end with 800 lbs. for a 12 ft. revetment and 600 lbs. for a 9 ft. revetment. Two braces, 2"x8", should be securely nailed, one to each vertical face of the sill and corresponding face of the post. The lower end of the post should be securely scabbed to the sill, on both faces, and toe-nailed to the sill as well. Cutting pavement and setting posts in the ground may require less effort than building standards.

The use of double headed nails in revetment construction will facilitate the repair of damage.

A 12 ft. section, weighing 980 lbs. may be easily tilted up by means of the line from a jeep winch, rigged over a gin-pole.

The boring and fastening of rails to posts by means of lag screws will be facilitated by nailing blocks to the posts for them to rest on. End splitting of rails may be prevented by bolting through them vertically adjacent to the lag screw holes with 1/4"D. bolts with washers under the heads and nuts.

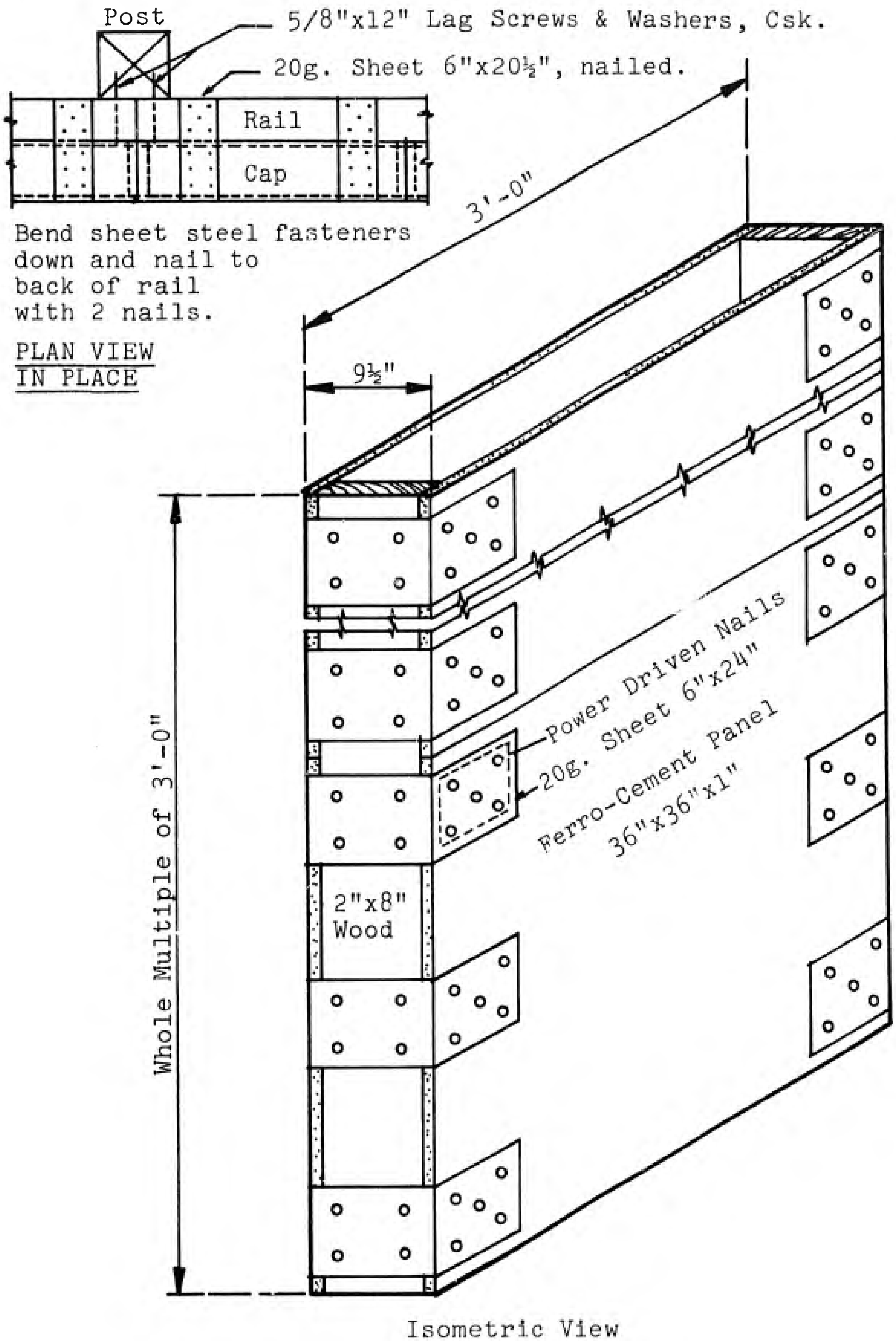


Figure 1 TILT-UP REVETMENT SECTION

The following sequence of steps in fabricating tilt-up sections will do away with necessity to turn a section over:

(1) Power nail the steel strips to the panels for one side, turn the panels over and arrange them with edges in contact.

(2) Position the 2x8's, bend the strips up and nail them.

(3) Position the panels for the other side on the edges of the 2x8's, bend the strips and power nail them.

The strips should be snug. In order to make them so, bend them around the corners with light blows of a wooden mallet directed to the corner. The first layer of panels should be laid out on sills to hold them true and provide access to the corners.

2.3 Blast Force from Near Bursts

Blast force from very near bursts will exert a considerable force on the revetment. The information presented in Table 1 provides an indication of the force exerted. The measurements of movement were made during experiments reported in Volume I of the report. They were a "by product" of the experiment; no effort was made to control the resistance to sliding. The soil surface was dry and very hard.

A time fuzed burst within revement height of the ground is improbable and a contact burst will occur close to the ground, therefore blast force is most likely to be delivered mainly on the lower panel of a revetment section. The force of a very near burst will overcome friction between the section and soil or pavement and cause it to slide a short distance and pivot about the rail at the top. By looking at the plan view in Figure 1, it can be seen that a section can pivot away from the post side of the revetment by merely bending the sheet steel fasteners, but if it pivots toward the post side it will either break the top fastenings or twist the rail, most likely damaging it. For this reason, a rail should be placed at ground level. Since it can be loaded only by force directed toward the post side, toe-nailing it to the post will be adequate and the sections need not be fastened to it.

Table 1 REARWARD SLIDING OF TWO 2"x8" SILLS CARRYING 485 LB. LOAD BY SHELL BLAST FORCES ON APPROXIMATELY 7 SQUARE FOOT AREA*

Shell	Distance from Panel	Movement
81mm Mortar	3'	19"
81mm Mortar	6'	3"
105mm Howitzer	5'	33"
105mm Howitzer	10'	11"
4.2 in.Mortar	5'	Not measured
4.2 in.Mortar	10'	Not measured

*Area of panel plus estimated area of similarly blasted parts of support.

2.4 Support Materials

In thinking of support strength, one is likely to think of structural steel. A blast that will break wooden timbers will bend steel enough to destroy its usefulness. It cannot be straightened except in a steel shop. Wood is easily replaced and all kinds of repair work can be done with a hammer, saw, and sturdy, rough-work chisel.

Section 3

Bunkers

3.1 Planned Defensive Positions

Bunkers will usually be a part of a planned defensive position prepared when personnel are not under fire. Under this condition, the walls of a bunker may be built as revetments (Par. 2.2) and 9 ft., 12 ft. or even 15 ft. revetment sections may be laid horizontally to provide two-panel in tandem overhead protection without roof beams. Nine foot sections should be supported at the center and 12 ft.

or 15 ft. sections at the third points, with timber or log caps on timber or log columns. With columns spaced at 9 ft., 6"x6" caps and columns (rough-sawn or nominal) will be adequate.

The only fire likely to enter the open ends of the roof sections will be on a flat trajectory, most likely bullets or horizontally flying shell fragments. The angle of incidence will make penetration of a panel improbable. The ends could be easily closed with earth filled bags.

3.2 Hasty Defenses

Where defensive action is undertaken in a meeting engagement and the defensive position is strengthened as there is opportunity, by improving natural or hastily dug-in-cover, 1" ferro cement panels light enough to be easily handled by one man will add significantly to the hastily prepared protection. A 1" panel 4 square feet in area will weigh 50 lbs. The panels may be square or rectangular. According to experimental results, ricochets will occur if the incident angle is 20° or less. Tilted panels have increased resistance to penetration by bullets or horizontally flying fragments. The most effective use of the panels will be to armor the forward slope of earth excavated in digging fox-holes or slit trenches. Availability of panels in a meeting engagement is problematical.

Section 4

Concrete Sky

4.1 General

This term was coined to describe a concept of arched concrete overall protection for aircraft. Ferro cement panels are particularly adaptable to this use. The essentiality of operable aircraft to the accomplishment of the military mission and the cost of replacing aircraft make this one of the most important military uses recommended for ferro cement panels. Several thin panels separated by air spaces extract far more energy from a bullet or fragment than the same amount of material in one thick slab.

4.2 The Panel Blanket Concept

This concept is illustrated in Figure 2. The hypothetical dimensions are only a basis to which to relate the number of panels and the maximum load on the connections of 4-panel corner junctions; the concept is applicable to any arch. The blanket is formed of multiple layers of 1" panels separated 6" or more by horizontal timber spacers. The minimum requirement is two layers. The blanket derives its stability from being draped over the arch. Each layer must be placed from the crown downward simultaneously on the two sides. Shingler's scaffolding should be used, stayed by lines rigged over sheaves so they may be payed out from the scaffolds.

The connections at the junctions of four panels are made with a 12"x12" piece of 20g. sheet steel fastened to the panels with power-driven nails. The maximum pull of one panel corner on the steel sheet is 290 lbs. without the assistance of friction with the arch geometry shown in Figure 2. Friction with a coefficient of 0.15 reduces the maximum pull to 220 lbs. The maximum pull occurs where the rise to run ratio of the slope is equal to the coefficient of friction. The connection is far in excess of theoretical requirements. The 4-nail connection to each panel will resist rotation of the sheet sufficiently to prevent one, or two adjacent, circumferential rows from sliding if severed by the destruction of panels.

Succeeding blanket layers of panels will be laid on timber spacers to provide 6" or more of separation. The spacers may be readily secured by nailing 20g. sheet steel strips to the side that will be placed down and power-nailing the strips to panels in the preceeding blanket layer. One circumferential row of panels all the way over the hypothetical arch drawn in Figure 2 requires 24 panels, 36"x36"x1". The angle change at the junction of panels in a row is 5-3/4 degrees. With the edges of the lower surface in contact, the edges of the upper surface will be separated about 3/32". The 20g. sheet may be bent by the force exerted by hand on the nail driving gun.

Several "concrete sky" concepts were scrutinized in detail. The one described presents the least faults and may be quickly and simply installed. Reference is made to Par. 4-8.3, page 4-146, Volume I, relative to the estimated effectiveness of two layers of 1" panels separated by a 6" air space.

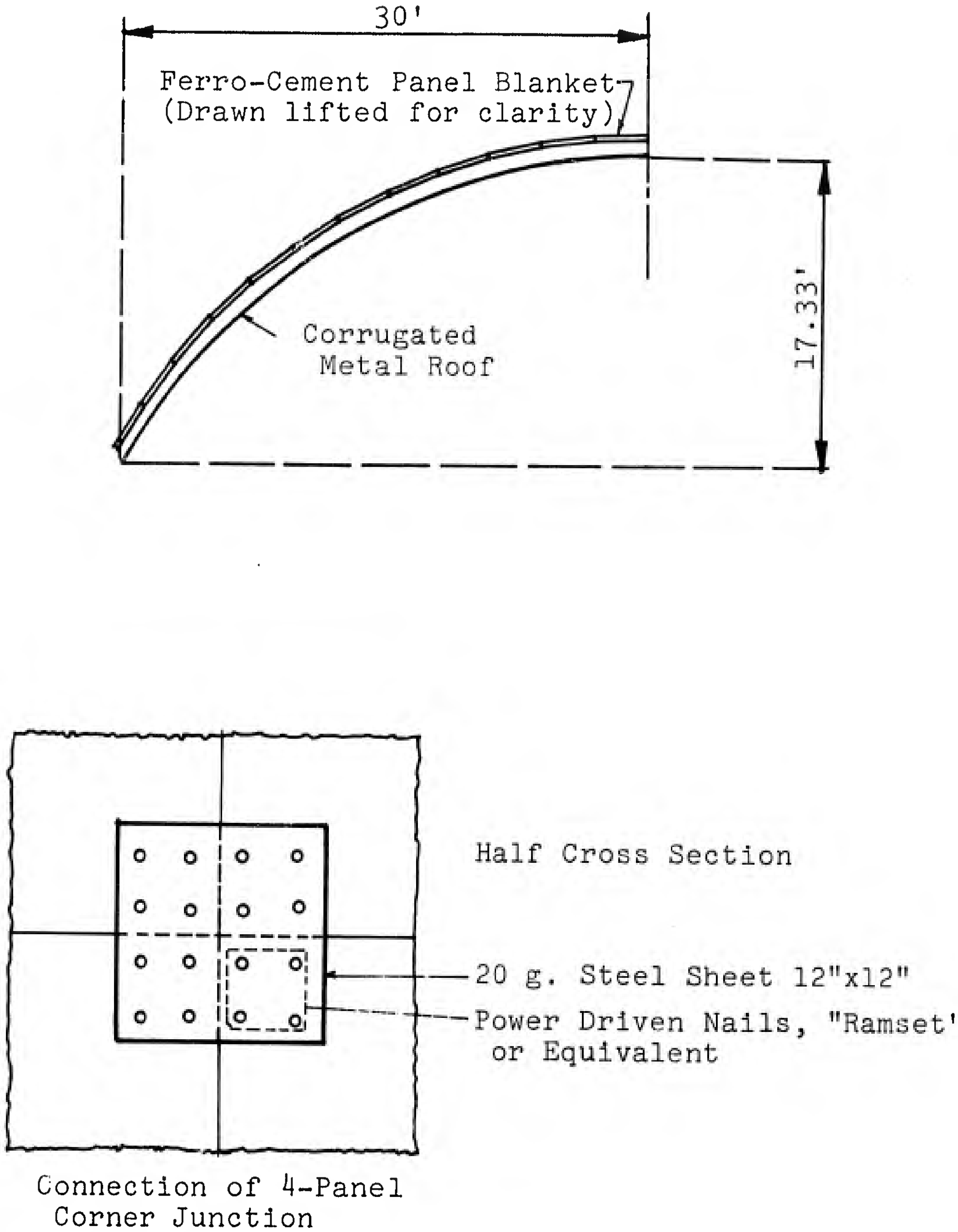


Figure 2 PANEL BLANKET ON
CORRUGATED METAL ROOF

Section 5

Bridge Protection

5.1 General

The results of experiments, in which ferro cement panels were exposed to demolition charges, indicate clearly that they provide protection by denying access to the pier, thereby forcing the attacker to place the charges at a standoff, which should be 6 feet or more. The energy absorbed by the panels is not significant in the energy magnitude of demolition charges.

Two enclosures of the pier, one within the other, should be provided in order to defend against attack by a two-man team, in which the second swimmer would gain access to the pier through the breach in the fender made by the first charge and place a second charge against the pier. The experiments revealed that the second panel in a two-panel tandem will not be destroyed if it is free to swing from a top edge suspension, but will be destroyed if it is rigidly supported. No feasible way seems available to permit the panels of the inner enclosure to swing when the charge is detonated on the outer enclosure and not swing when a second swimmer attempts to insert a charge. Furthermore, the supports would have to be outside the inner enclosure for the panels to swing inward and would have less protection.

It seems apparent that a means to gain some additional energy absorption by the two enclosures, constituting the fender, must be provided.

5.2 The Sandwich Fender Module

If the shock wave path through an elastic substance is interrupted by a layer of another substance having a different wave length, the impedance to propagation of shock waves is increased. Advantage may be taken of this phenomenon by constructing each enclosure of 4'x4' modules, each fabricated of two 4'x4'x2" panels separated by 4"x6" (nominal) wood fills around three edges, with the 3'-1"x 3'-1"x3½" cavity filled with urethane or expanded polystyrene foam. The details of a sandwich module are shown in Figure 3.

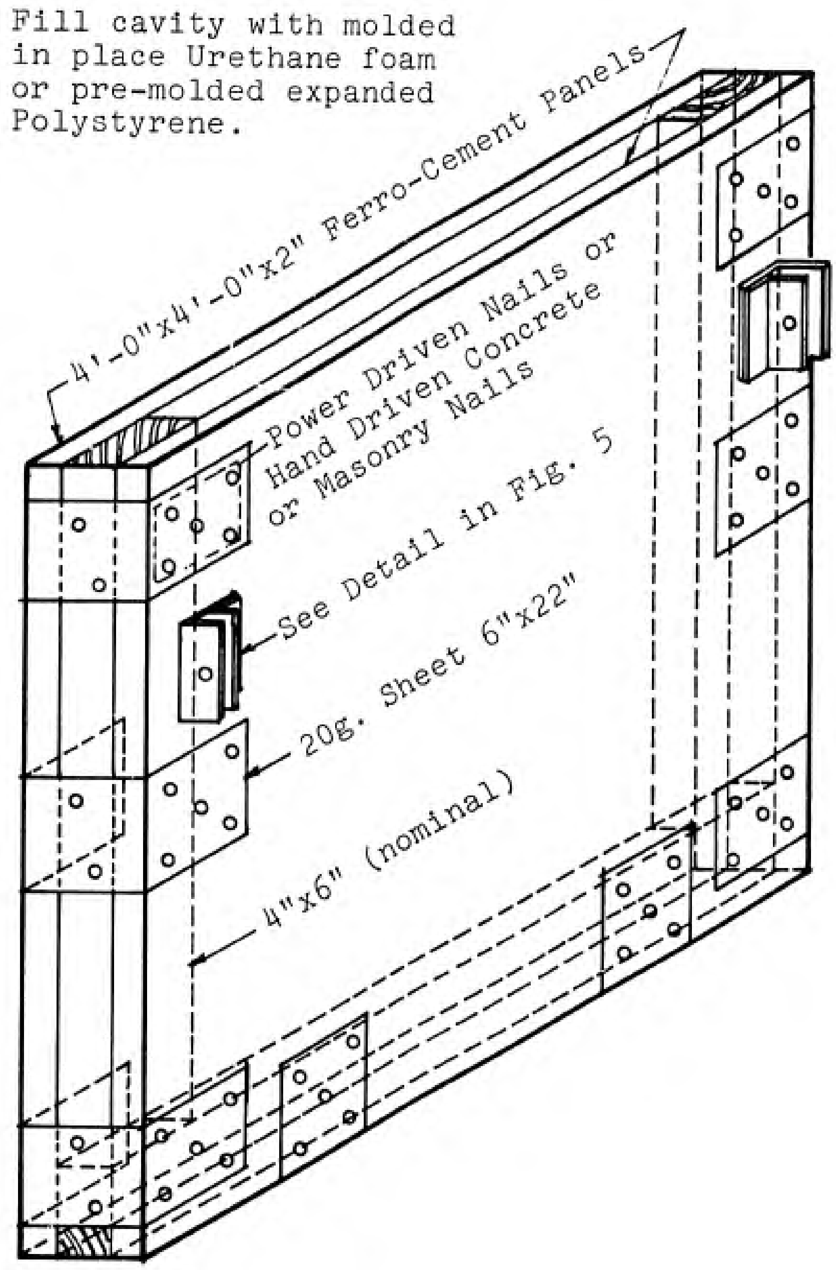


Figure 3 SANDWICH MODULE FOR
PIER FENDERS

The advantages of sandwich modular construction are:

(a) Increased shock wave impedance provided by foam.

(b) Four ferro cement panels in two enclosures attain some resistive significance.

(c) The 7½" thickness of the module opens the door to a wider choice of supporting methods than is available with single 2" panels.

(d) Buoyancy will facilitate underwater handling of replacement modules.

The sandwich modules are fabricated in the same manner as tilt-up revetment sections (Section 2).

The cost of urethane foam is from 1.5 to 2.0 times the cost of polystyrene foam, but urethane has a logistical advantage that may offset the difference in cost of the material. Expanded polystyrene may be produced only in the manufacturing plant and must be shipped and land transported in panels of its premoulded dimension. Urethane foam may be produced from the liquid urethane and catalyzer in the cavity of the sandwich module as a part of the fabrication operation. The necessary equipment costs around $5,000 per set and is transportable in a light truck.

The probable maximum and minimum weight, displacement and underwater dead load of a module, as detailed in Figure 3, is given in Table 2.

Table 2 SUMMARY OF WEIGHTS, DISPLACEMENT AND UNDERWATER DEAD LOAD OF SANDWICH FENDER MODULE

Material	Density (pcf) Max.	Density (pcf) Min.	Weight (lb.) Max.	Weight (lb.) Min.
Ferro-Cement Panels	153	139	815	740
Wood	45	24	77	41
Foam	2	1	10	5
Steel	490	490	7	7
Weight			909	793
Displacement			620	620
Underwater Dead Load			289	173

5.3 Assembly and Support of the Modules

The use of piles for the primary support of the pier fender is rejected for the following reasons:

(a) The pile tips are likely to encounter footings, seal courses or caisson tops before the pile has enough penetration for stability.

(b) A demolition charge on the outside surface opposite a pile will sever a wood or concrete pile and will seriously bend a steel pile if it does not cut it.

(c) The superstructures of many bridges will obstruct the headroom necessary for sticking and driving piles.

The most practicable means of supporting the modules is to suspend them from overhead beams in vertical tiers, by means of two 7-wire strands per tier. This concept is delineated in Figure 4, which is a longitudinal section of a fairly typical highway bridge of the probable average age. The section is taken at a pier at the junction of a concrete deck-girder side span and a steel truss channel span, thus presenting two conditions affecting the suspension of the overhead beams from the superstructure which is taken up in Paragraph 5.4.

Wire strands are available in several grades. The breaking strengths of 3/8" 7-wire strand, as quoted by the Bethlehem Steel Company are given in Table 3.

Table 3 BREAKING STRENGTHS OF 3/8" 7-WIRE STRAND

Grade	Min. Br. Str. (lb.)
Common	4250
Siemens-Martin	6950
High Strength	10800
Utilities	11500
Extra High Strength	15400

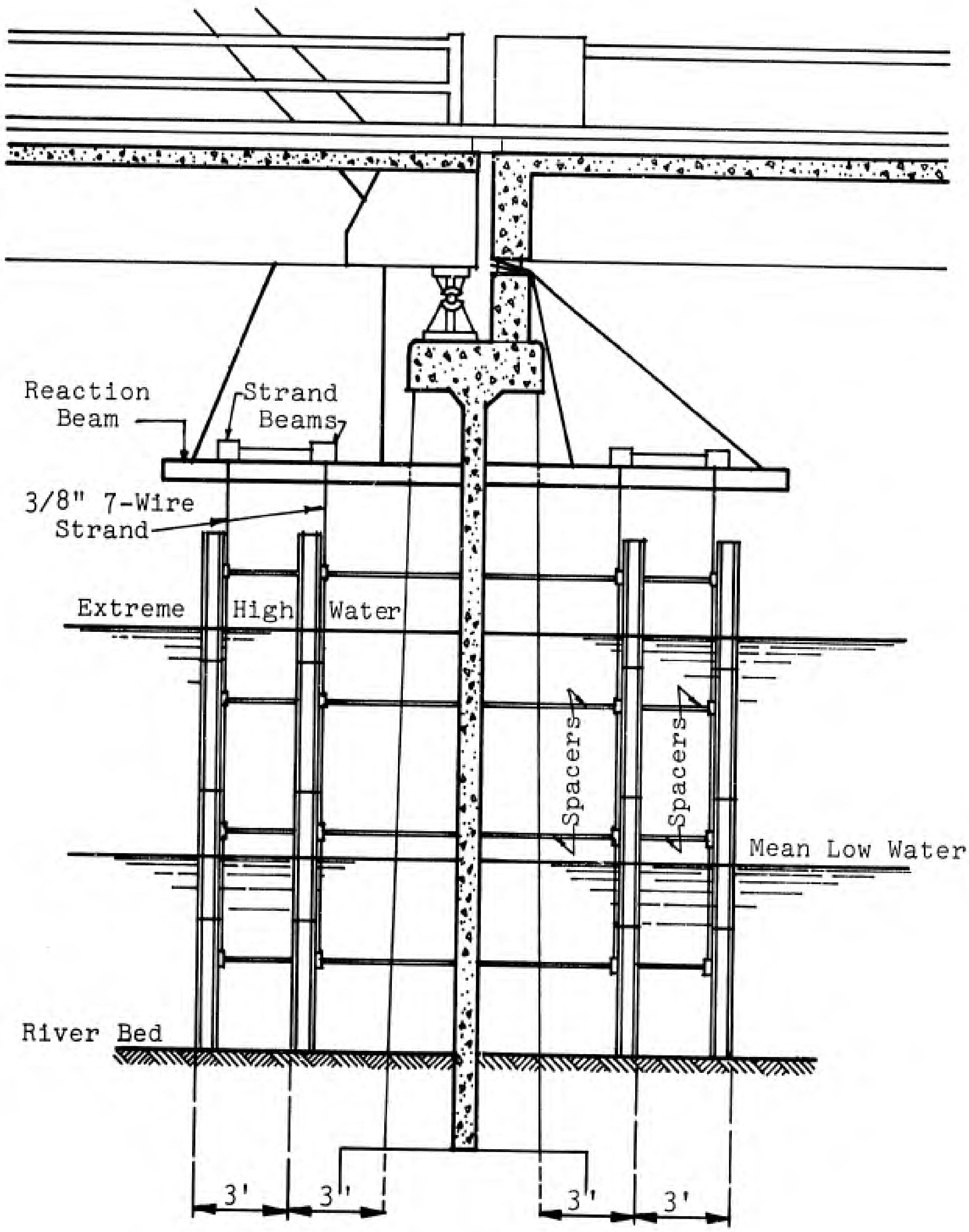


Figure 4 SUSPENSION OF PIER FENDER
FROM THE SUPERSTRUCTURE

For the conditions in Figure 4 with extreme low water assumed to submerge only one module per tier, the tension per wire strand produced by the dead load of the modules at maximum density is 1508 lbs., leaving a margin of 2742 lbs. with common grade strand for added tension due to surge and turbul nce caused by a demolition charge. For higher fenders, tension may be readily determined from the data in Table 2.

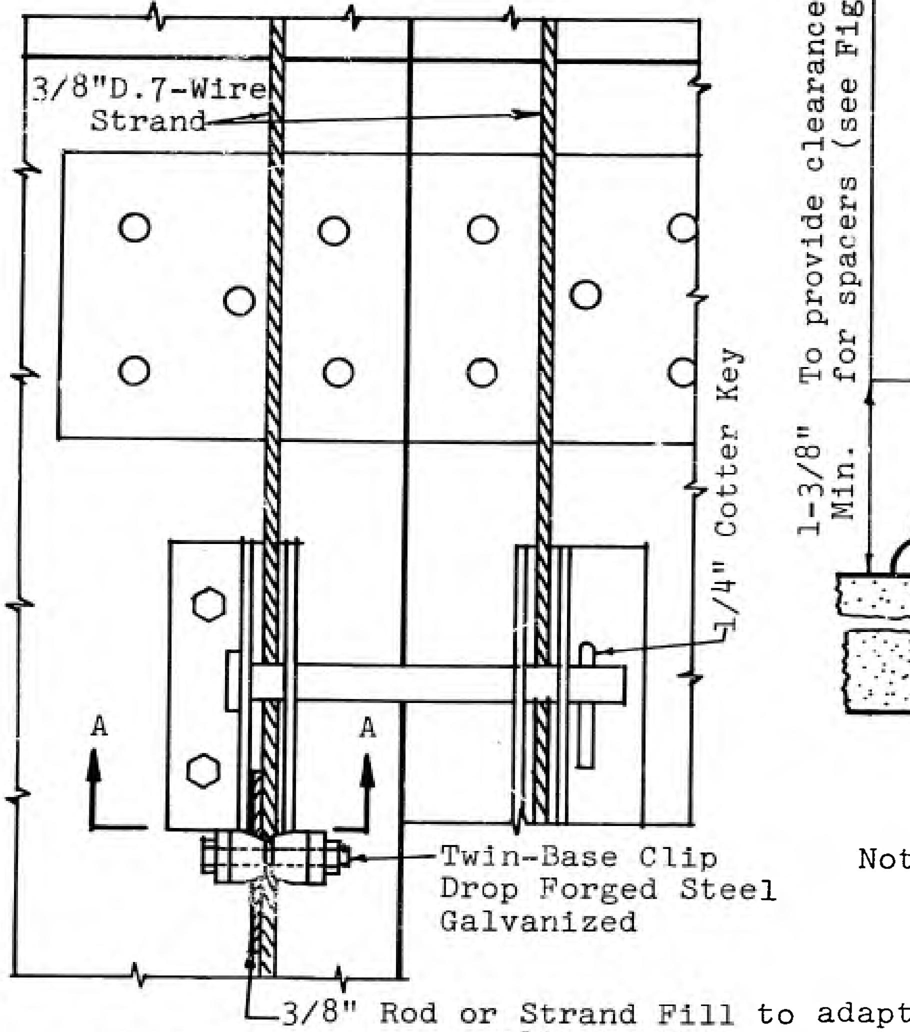
The details of attachment of the modules to the wire strand and lateral connection, module to module, are shown in Figure 5. The twin-base clips are used for cable clamps because they are an off-the-shelf item. They are manufactured and sold for clipping the dead end of a cable to the live portion where it is brought around a thimble and require fills, as shown in Figure 5, in order to be used as clamps. The maximum dead load per clip is 455 lbs.

The spacers (Figure 6) are inserted behind the 3/4" D. cotter pin between the backs of the 2½"x2½"x3/16" angles (Figure 5). The spacers are intended to be no more than adequate to restrain the two enclosures against sway by the river current. It will be advantageous for spacers in the vicinity of a demolition charge to buckle and leave the enclosures free to sway. The spacers are easily made and replaced.

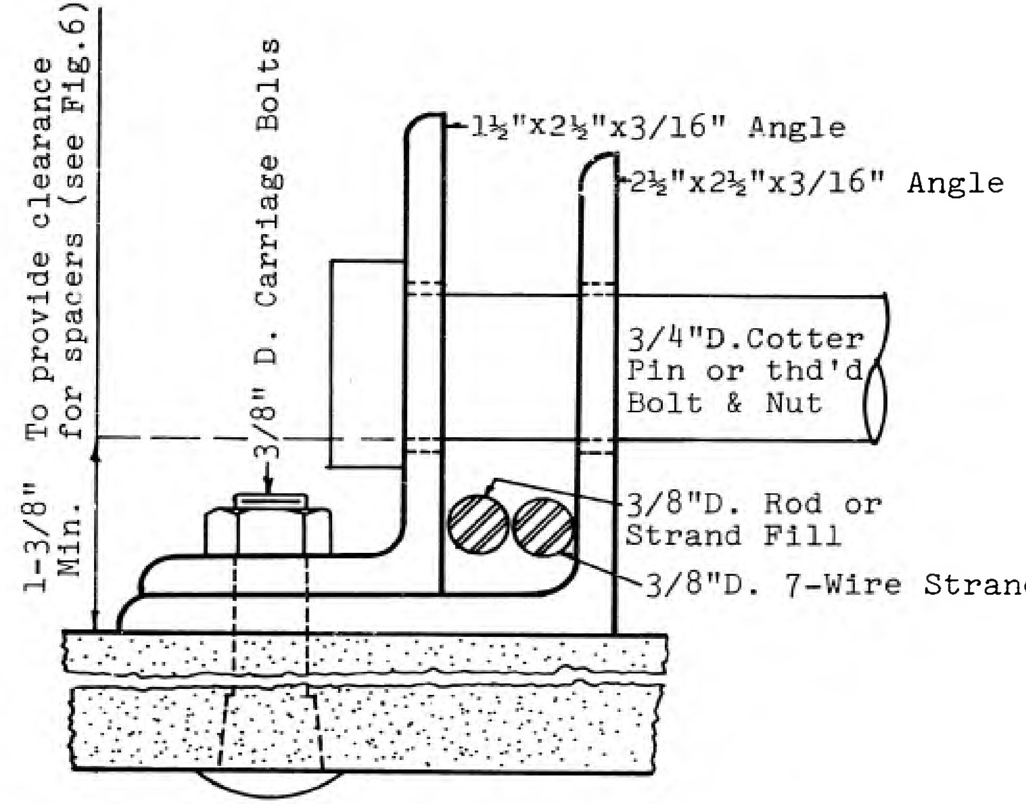
5.4 Overhead Support of the Fender

Figure 4 shows the 3/8" wire strand anchored to the strand beams, which are supported on reaction beams. The reaction beams are suspended from the superstructure.

In order to keep the required size of the timber beams within reasonable bounds, the overhead fender support is divided into sections not exceeding 12 ft. in length as shown in Figure 7. The strand beam capacities are given in Table 4 for sizes of timbers as noted and the 12 ft. span. The applied load is the dead load of one vertical tier of sandwich modules, which can be determined from the data in Table 2. These capacities are based on an extreme fiber stress of 1400 psi, which is conservative for any crib timbers other than Eastern Hemlock or Norway Pine, of Utility Structural Grade. These two varieties should not exceed 1200 psi.



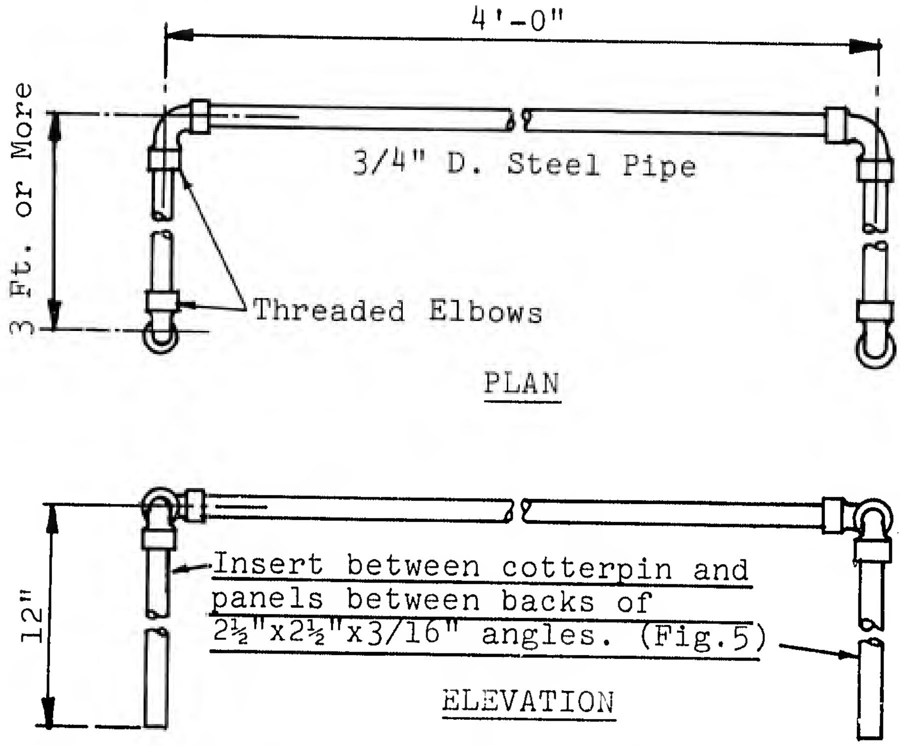
Part Elevation



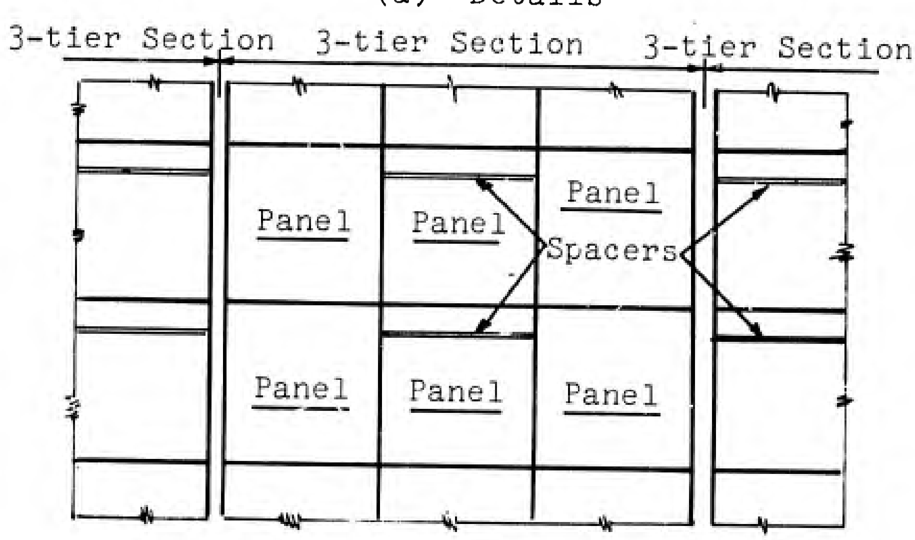
Section A-A

Notes: 3/4" Pins at interior joints of sections may be placed before lowering. Use pieces of rod or heavy wire at ends of sections to retain strands temporarily and install pins after lowering.

Figure 5 DETAILS OF SUPPORT AND CONNECTION OF SANDWICH PANELS



(a) Details



(b) Positioning

Figure 6 SPACERS

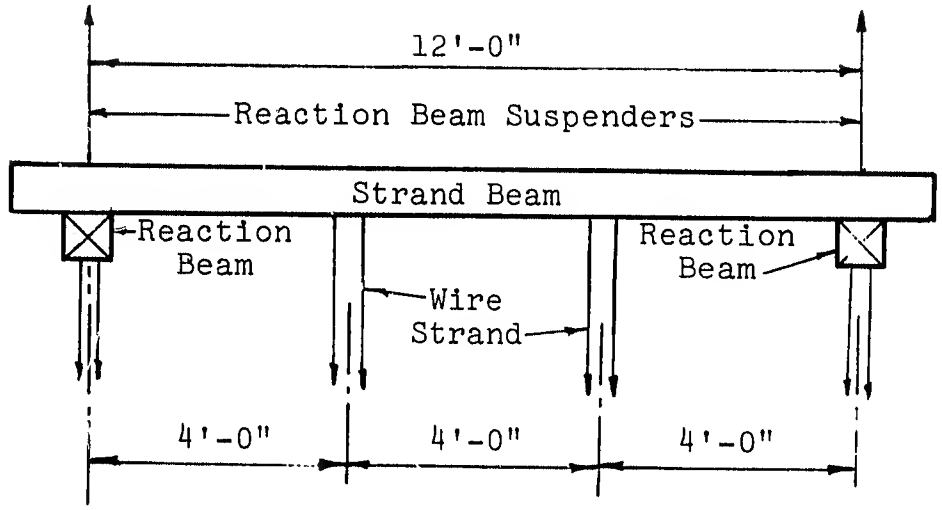


Figure 7 OVERHEAD FENDER SUPPORT SECTION

Table 4 STRAND BEAM CAPACITIES
(Allowable Load of 1 Vertical Tier of Sandwich Module)

Timber Size	Allowable Load (lb.)
10"x10" Rough Sawn	4900
10"x10" Nominal	4200
8"x8" Rough Sawn	2500
8"x8" Nominal	2100

The required size of the reaction beams is controlled by the allowable shear stress parallel to the grain. Reaction beams of the same size as the strand beams are conservatively sized for this condition. The shear resistances, parallel to the grain are given in Table 5. These values are based on an allowable stress of 100 psi which is conservative for this type of construction.

Table 5 REACTION BEAM CAPACITIES

(Allowable Load of 1 Vertical Tier of Sandwich Module)

Timber Size	Allowable Load (lb.)
10"x10" Rough Sawn	6600
10"x10" Nominal	6000
8"x8" Rough Sawn	4200
8"x8" Nominal	3750

It is to be noted that the reaction beams of adjacent overhead fender support sections will be 4 ft. apart.

The reaction beam suspenders, which attach to the superstructure, should have 17,000 lb. breaking strength where they incline 45° from the vertical and 12,000 lbs. for vertical cables, for fenders 20 ft. high where the low water stage may go as low as 4 ft. Wire strand of this capacity would be inconveniently stiff for making many of the connections. Wire rope of the Bethlehem Steel Company designation, "6x25 filler wire Type W construction with independent wire rope core," or equivalent, in 7/16" diameter is recommended. It is more flexible than most wire ropes of the same diameter and has become practically standard on industrial and construction applications.

5.5 Attachment to the Superstructure

Conditions affecting the opportunity to connect the reaction beam suspenders effectively vary considerably. It is believed that several general guides will provide the basis for designing connections after the underside of the superstructure has been examined.

(a) Suspenders may be anchored to the lower chords of trusses providing the anchorage is made within about 18 inches of the gusset plate. Lower chords do not have cover plates, so the anchorage can be made readily.

(b) Anchorages may be made by means of a steel beam or heavy crib timber spanning between bottom flanges of stringers. The ends of the beam or crib should be as close to the stringer web as possible.

(c) There normally will be a space between the end web of concrete deck girders and the back wall of the pier, through which a wire rope may be passed. The bearing plates are usually well enough anchored to have the wire rope passed around them and clipped.

(d) Wire rope may be passed over the pier between shoes of adjacent trusses or steel girders, thus running from a reaction beam on one side of the pier to one on the opposite side.

(e) Truss shoes may be used as anchorages.

(f) Where there is no space between a concrete span and the pier or bent, the only feasible solution is to break out an opening in the curb and rail on each side, lay an I-beam across the roadway and build a ramp over it.

(g) The lower lateral bracing of trusses and girders lacks sufficient beam strength for anchoring the reaction beam suspenders.

5.6 Ends of Fenders

The pressure of water on the upstream end of the fender is given by the formula, $P=kwV^2/2g$, in which w is the weight of water in pounds per cubic foot, V is the velocity of the stream in feet per second, g is the acceleration of gravity, k is a factor depending on the shape of the upstream end and P is the pressure per square foot perpendicular to the faces of the sandwich modules. By substituting the values of w and g, the formula is reduced to $P=0.975kV^2$, which may

further be simplified to $P=kV^2$. The values of k are 1-1/3 for square ends, 1/2 for pointed ends where the modules are at an angle of 30° or less with the direction of flow and 3/4 where the angle is approximately 45°. Where the velocity is known in statute miles per hour, it may be converted to feet per second by multiplying it by 1-1/2. Knots are converted to feet per second by multiplying by 1.7. Six statute miles per hour is a high, bank-full velocity for rivers with mean low water stage of 8 ft. or more. This velocity would exert the following forces: 1720 lbs. with square ends; 960 lbs. for 45° ends and 640 lbs. where the modules are at an angle of 30° with the direction of flow. Since the force varies as the square of the velocity, the above forces may be multiplied by the following factors for lesser velocities: 0.7 for 5 miles per hour; 0.45 for 4 miles per hour and 0.25 for 3 miles per hour.

The plan and elevation of a fender around a pier is shown, diagrammatically, in Figure 8, with the upstream end at an angle of about 45° with the current. The end supports and spacers may be designed by making use of applicable guides stated in Paragraph 5.5.

5.7 Flash Flooding Rivers

Rivers which rise in mountainous areas usually have a very shallow mean low water stage across the foothill plain, but are subject to flash floods which have a fast moving steeply inclined crest front. Since the water level inside the fender can rise only as fast as water can pass between the edges of fender modules, it may be necessary to take precautions against the occurrence of unaccpetable hydrostatic pressure on the entire surfaces of both enclosures. The enclosed water surface area in Figure 8 is about 700 square feet. A river stage rise of 3 ft. per hour could be matched within the fender by pumping with a total pump capacity of 250 gallons per minute. Flash floods recede on a backwater curve which has a far more gradual slope than the crest front. The shallow mean low water stage and high velocity flood stage of such rivers should lessen the probability of attack by underwater swimmers.

5.8 Bents and Abutments

Bents consist of two or more square columns on footings supporting a beam across their tops which supports the superstructure. If a bent is tall, there will be a cross-tie between columns at about their mid-height. Bents normally support approach spans which are shorter than the channel

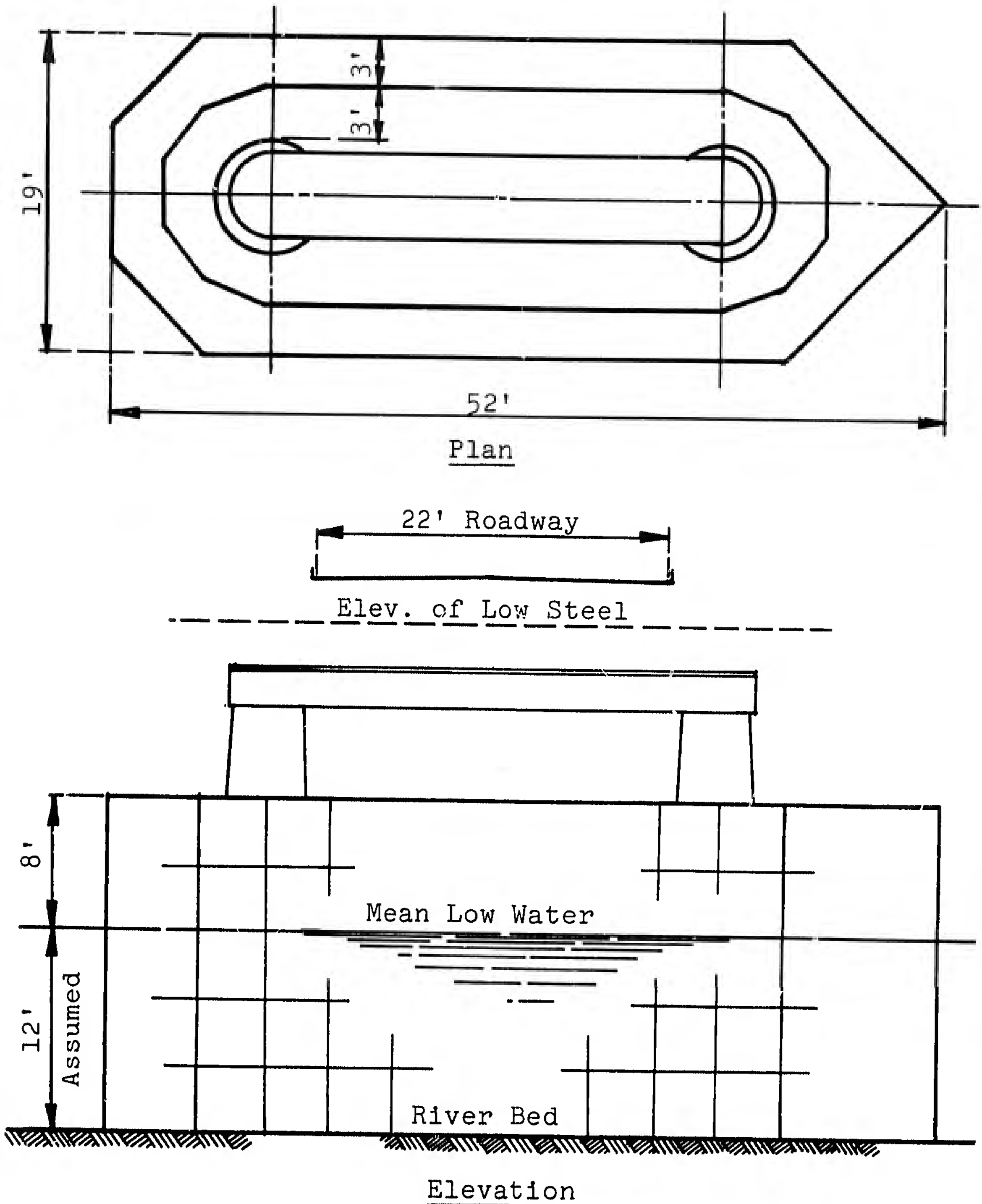


Figure 8 DUAL ENCLOSURE PIER FENDER
OF SANDWICH FENDER MODULES

spans. The detail at the top surface of the beam will usually be similar to that at the top of the pier backwall supporting the concrete deck-girder span in Figure 4, and the reaction beam suspenders may be passed over the top of the beam underneath the superstructure end webs. Abutments of rural bridges are usually back of the mean low water shore line. In congested urban areas there may be deep water at the frontwall, in which event the end span is likely to be steel, offering ready anchorages for reaction beam suspenders. The abutment backwall will be just shoreward of the extreme end of the superstructure and rise to the underside of the street pavement. The superstructure span will bear on the bridge seat which is forward of the backwall. If the end span is a concrete deck girder there will be a space between the end web and the bridge seat which will permit the reaction beam suspenders to be passed around the bearing plates. The free end of the wire rope will probably have to be retrieved with a hook or by means of a hemp lead line previously secured to it.

5.9 Useful Appurtenances in Construction Applications of Wire Strand and Wire Rope

A sketch of 7-wire strand is shown in Figure 9. Several useful appurtenances are shown in Figures 10 through 17. Extraction of Figures 9 through 17 from the Bethlehem Steel Company Catalog 248-A is acknowledged. Reference is made to remarks concerning the use of twin-base clips as cable clamps in Paragraph 5.3 and as shown in Figure 5. A positive cable clamp is shown in Figure 11. These are normally used for clamping wire rope suspension bridge main cables at the tower saddles to prevent slippage and are custom made to the designer's specification.

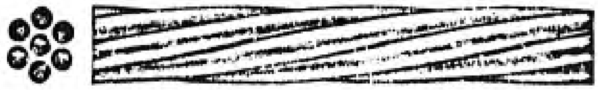
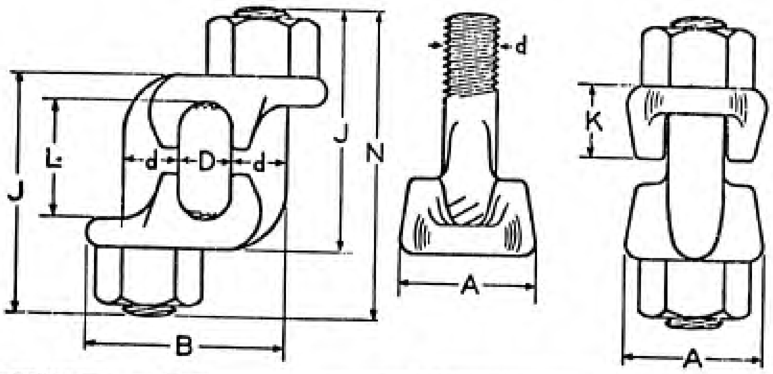


Figure 9 SEVEN-WIRE STRAND



Diam of Rope in.	Dimensions								Weight
	A in.	B in.	D in.	d in.	J in.	K in.	L in.	N approx in.	lb
1/4	15/16	1 1/4	1/4	3/8	1 1/4	21/64	1/2	1 3/4	0.21
5/16	1 1/16	1 11/32	5/16	3/8	1 15/32	7/16	5/8	1 13/16	.26
3/8	1 1/8	1 37/64	3/8	7/16	1 13/16	31/64	3/4	2 3/16	.38
7/16	1 1/4	1 7/8	7/16	1/2	2 11/64	9/16	1	2 3/4	.60

Figure 10 TWIN BASE CLIPS

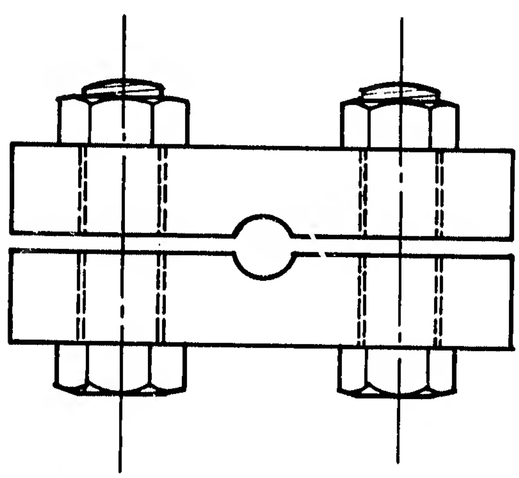
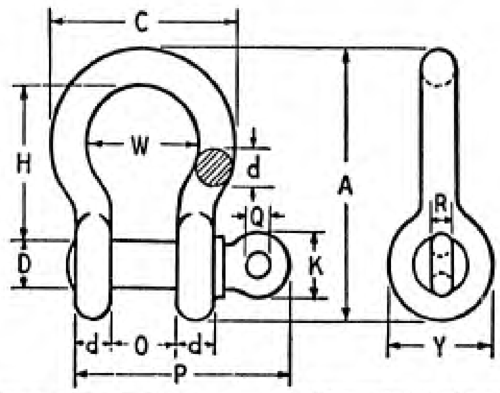
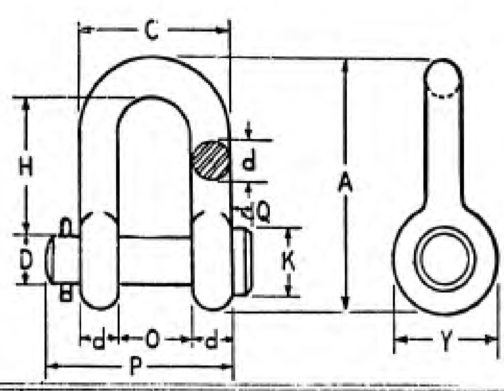


Figure 11 WIRE ROPE CLAMP
(Custom made to designer's specification)



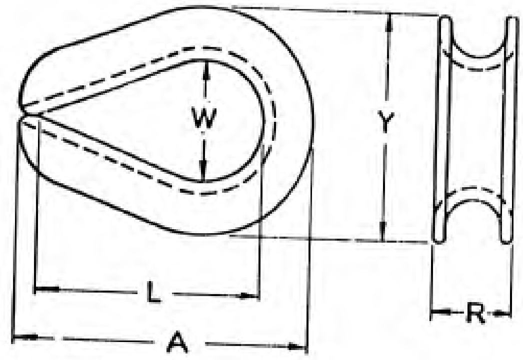
Size of Shackle d in.	A approx in.	C in.	D in.	H in.	Tol. H ± in.	K approx in.	O in.	Tol. O ± in.	P approx in.	Q approx in.	R approx in.	W approx in.	Y in.	Weight lb	Breaking Strength tons
1/4	1 7/8	1 9/32	5/16	1 1/8	1/16	7/16	15/32	1/16	1 15/32	5/32	5/64	25/32	1 1/16	0.12	2
5/16	2 1/8	1 15/32	3/8	1 1/4	1/16	9/16	17/32	1/16	1 3/4	3/16	3/16	27/32	13/16	.18	3
3/8	2 17/32	1 25/32	7/16	1 1/2	1/8	5/8	21/32	1/16	2 1/16	7/32	13/64	1 1/32	31/32	.32	4
7/16	2 15/16	2 1/32	1/2	1 3/4	1/8	23/32	23/32	1/16	2 11/32	1/4	15/64	1 5/32	1 1/8	.49	6

Figure 12 SCREW PIN ANCHOR SHACKLES



Size of Shackle d in.	A in.	C in.	D in.	H in.	Tol. H ± in.	K in.	O in.	Tol. O ± in.	P in.	Q in.	Y in.	Weight lb	Breaking Strength tons
1/4	1 5/8	31/32	5/16	7/8	1/16	1/2	15/32	1/16	1 1/4	3/16	11/16	0.11	2
5/16	1 15/16	1 5/32	3/8	1 1/32	1/16	9/16	17/32	1/16	1 1/2	3/16	13/16	.17	3
3/8	2 21/64	1 13/32	7/16	1 1/4	1/16	5/8	21/32	1/16	1 3/4	3/16	31/32	.28	4
7/16	2 23/32	1 19/32	1/2	1 1/2	1/16	11/16	23/32	1/16	1 7/8	3/16	1 1/16	.42	6

Figure 13 ROUND PIN CHAIN SHACKLES



Rope Diam in.	A approx in.	L in.	R in.	W in.	Y in.	Max Pin Diam in.	Weight approx lb
1/4	2 3/8	1 5/8	13/32	7/8	1 1/2	13/16	0.06
5/16	2 3/4	1 7/8	1/2	1 1/16	1 13/16	15/16	.12
3/8	3 3/8	2 1/8	21/32	1 1/8	2 1/8	1 1/16	.25
7/16	3 9/16	2 3/8	3/4	1 1/4	2 3/8	1 3/16	.37

Figure 14 WIRE ROPE THIMBLES

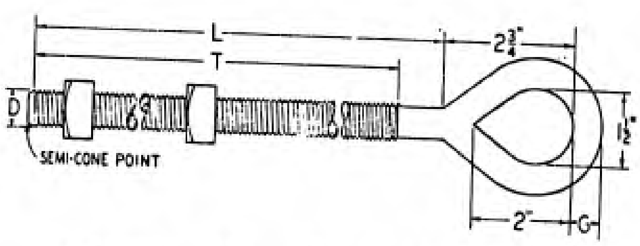


Figure 15 OVAL-EYE BOLTS

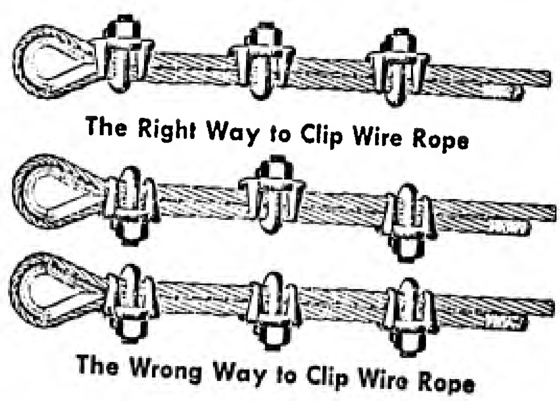
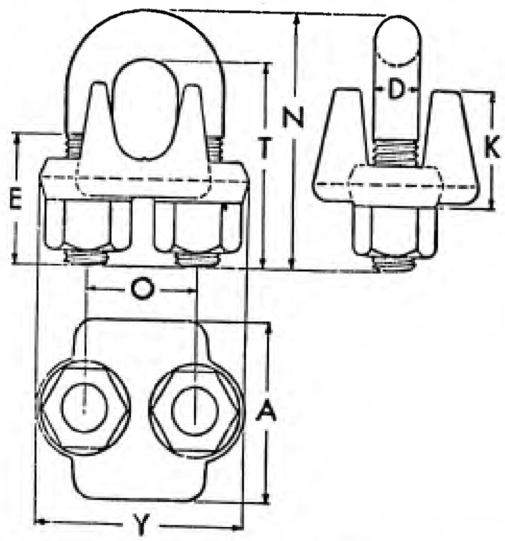


Figure 16 CLIPPING WIRE ROPE



Diam of Rope in.	A in.	D in.	E in.	K in.	N in.	O in.	T in.	Y in.	Weight lb
1/8	13/16	7/32	7/16	25/64	15/16	15/32	23/32	15/16	0.05
3/16	15/16	1/4	9/16	1/2	1 7/32	19/32	31/32	1 3/32	.10
1/4	1 3/16	5/16	5/8	2 1/32	1 11/32	3/4	1 1/32	1 7/16	.19
5/16	1 5/16	3/8	3/4	2 3/32	1 11/16	7/8	1 5/16	1 11/16	.29
3/8	1 5/8	7/16	13/16	2 9/32	1 15/16	1	1 1/2	1 15/16	.47
7/16	1 13/16	1/2	1 1/16	1 1/64	2 3/8	1 3/16	1 7/8	2 9/32	.70

Figure 17 U-BOLT CLIPS

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13. ABSTRACT

Military uses and installation of ferro cement panels are presented, based on conclusions reported in Volume I.

Tilt-up construction of revetments is recommeded, with sections 3' wide and a multiple of 3' in height, of two layers of 3'x3'x1" panels secured at their vertical edges to wood 2x8's. Support is provided by posts at 9' centers and a rail to which tops of sections are secured.

Revetment sections are recommended for the walls and roof of bunkers in prepared defensive positions. In hasty defense resulting from a meeting engagement, single 1" panels about 4 square feet in area will reinforce hastily dug-in protection. Their availability in a meeting engagement is problematical.

For "concrete sky", blanketing layers of 3'x3'x1" panels fabricated in place over an arched supporting structure is recommended, with multiple layers separated 6" by timber spacers secured to the layer beneath them.

For pier fenders, it is recommended that pre-fabricated sections of two 4'x4'x2" panels secured to wood 4x6's, filled with urethane or polystyrene foam, be suspended from the bridge superstructure by means of steel wire strands.

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Bridge						
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Fenders						
Ferro Cement						
Foam filled						
Military						
Panels						
Pin						
Power nails						
Prefabricated						
Protection						
Ram-set						
Revetments						
Tilt-up						
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